Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-013-2570-7

Thermoelectric Power Generation Utilizing the Waste Heat from a Biomass Boiler

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The objective of the presented work is to test the possibility of using thermoelectric power to convert flue gas waste heat from a small-scale domestic pellet boiler, and to assess the influence of a thermoelectric generator on its function. A prototype of the generator, able to be connected to an existing device, was designed, constructed, and tested. The performance of the generator as well as the impact of the generator on the operation of the boiler was investigated under various operating conditions. The boiler gained auxiliary power and could become a combined heat and power unit allowing self-sufficient operation. The created unit represents an independent source of electricity with effective use of fuel.

Key words: Thermoelectric generator, waste heat, boiler, flue gas

Nomenclature

V_{OC}	TEG open-circuit voltage
I_{SC}	TEG short-circuit current
r_{in}	Internal resistance of a TE module
η_{TE}	Conversion efficiency of a TE module
η_B	Thermal energy efficiency of the biomass boiler
T_H	TE module hot-side temperature
T_C	TE module cold-side temperature
λ	Air ratio in the combustion process

INTRODUCTION

Thermoelectric power conversion enables generation of electric energy from accessible waste heat sources.[1–4] In cases when the operating medium's mass flow or temperature fluctuates, or in the case of low-temperature waste heat, conventional conversion methods are limited. In these cases, thermoelectric power conversion might be an effective method for generating high-quality electric power. Such cases are represented for instance by local residential boilers, such as small-scale pellet boilers, which may generate power at the level of kW and also release more waste thermal energy into the atmosphere uselessly. Thermoelectric generators (TEGs) have potential to recover waste heat as effective energy and make important contributions to reduce fuel consumption.[5,6] Thermoelectric systems have no moving particles or chemical substances and are maintenance-free and silent in operation, reliable, and independent of position. The generated electrical energy can be used, e.g., for power supply or charging batteries. The major disadvantage of TEGs is the low energy efficiency. In addition, the energy efficiency and released output power are temperature dependent. Within the scope of this paper, a TEG using waste heat was designed, constructed, and tested on a biomass boiler. The objective is to construct a TEG connectible to a combustor without the need to interfere with its construction. Simultaneously, the boiler generator must be designed to recover the allowable waste heat output without dropping the flue gas temperature below the condensation point, otherwise there would be low-temperature corrosion and damage of the flue gas duct.

(Received July 9, 2012; accepted March 6, 2013; published online April 20, 2013)

EXPERIMENTAL PROCEDURES

Construction of the Prototype

The experimental device consists of a biomass boiler and a designed external TEG (Fig. 1) located